Mines and Minerals Division

Ontario Geological Survey
Open File Report 5580

Mineral Aggregate Resources Inventory of the County of Lennox and Addington

Southern Ontario

1987

Ontario

Ministry of
Northern Development
and Mines

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MINES AND MINERALS DIVISION

ONTARIO GEOLOGICAL SURVEY

Open File Report 5580

Mineral Aggregate Resources Inventory of the County of Lennox and Addington Southern Ontario

by

Staff of the Eastern Region
Ontario Ministry of Natural Resources

1987

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V.G. Milne

V.G. Milne, Director
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FOREWORD

This report presents an inventory of mineral aggregate resources in the County of Lennox and Addington. The maps accompanying this report delineate the areas of the best sand and gravel and crushed stone resources. This information is presented so that land use planning strategies can be developed that will allow the fullest use of these valuable materials.

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P. 2974 Sand and Gravel Assessment of Lennox and Addington County - Central Sheet; Anglesea, Kaladar, and Sheffield Townships, scale 1:50 000.

P. 2975 Sand and Gravel Assessment of Lennox and Addington County - North Sheet; Ashby, Denbigh, Effingham, and Abinger Townships, scale 1:50 000.

P. 2976 Bedrock Aggregate Assessment of Lennox and Addington County - South Sheet; Richmond, Camden East, North Fredericksburgh, Ernestown, Adolphustown, South Fredericksburgh, and Amherst Island Townships, scale 1:50 000.

ABSTRACT

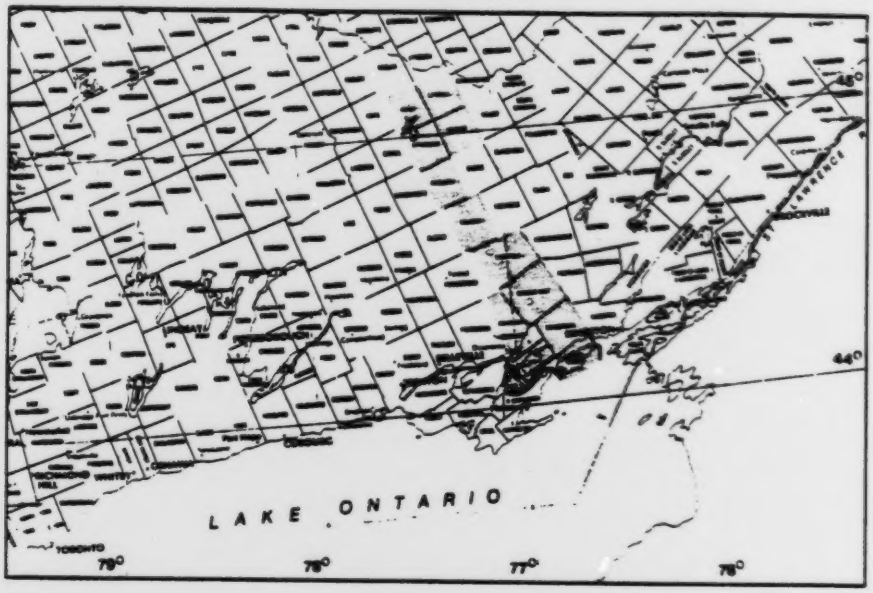

Figure 1 - Key Map Showing Location of the County of Lennox and Addington, Southern Ontario. Scale 1:3 000 000.

This report includes both an inventory and analysis of sand and gravel, as well as bedrock resources, in the County of Lennox and Addington. The assessment was undertaken by the Ontario Ministry of Natural Resources, Eastern Region, according to standards established in the F.K. Aggregate Classification System.

There are approximately 164.91 million cubic metres of sand and gravel available within the county. However, the resources are not distributed evenly. Three townships - Abinger, Denbigh, and Kaladar - have 133.05 million cubic metres, or over 80 percent of the available material. These townships also possess over 65 percent of the total Class "1" resources in the county. The

townships south of King's Highway 7 have few reserves of high quality sand and gravel, however, this may be compensated for by the possible bedrock aggregate resources available.

Bedrock aggregate resources are concentrated within the southern part of the county. The Paleozoic age rocks are thinly drift covered and extensive areas of high quality resources are available. Bedrock suitable for Class "1" uses occurs in the southeast corner of the county within the Gull River Formation. Class "2" materials occur within both the Gull River and Bobcaygeon Formations and Class "3" materials occur within the Verulam Formation. Formation thickness data necessary for bedrock resource assessment were unavailable. Consequently, calculations of the bedrock resources in the County of Lennox and Addington were not included in this inventory.

MINERAL AGGREGATE RESOURCES INVENTORY OF THE COUNTY OF LENNOX AND ADDINGTON, SOUTHERN ONTARIO[1]

INTRODUCTION

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1982, the total tonnage of mineral aggregates extracted was 92 million tonnes, greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1983).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in urban fringe areas where land use competition is extreme. For these reasons the availability of adequate resources for future

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development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Mineral Aggregate Resources Inventory of the County of Lennox and Addington is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies and official plans. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of a municipality's resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential of bedrock-derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

PART I - INVENTORY METHODS

FIELD AND OFFICE METHODS

Sand and Gravel Resources

The methods used to evaluate the sand and gravel resources in the County of Lennox and Addington involved integrated field and office procedures. Topographic maps of the National Topographic System, at a scale of 1:50 000, were used as a compilation base for the field and office data.

An initial reconnaissance of the county located the sand and gravel pits which were described and sketched. This information was used to estimate the amount of material previously removed and to provide a firm base for the final assessment.

In the office, published geological data, such as surficial goelogy maps and reports, were carefully examined. Black and white aerial photographs with approximate scales of 1:50 000, 1:37 000, and 1:15 000 were also used to locate features with sand and gravel potential. Water well records held by the Ontario Ministry of the Environment were used to corroborate thickness estimates or to indicate the presence of buried granular material.

The field investigations were intensive and included the taking of samples and noting the sand/gravel ratio, the grain size of the sand, the silt and clay content, and the amount of deleterious material, such as shale and siltstone. The amount of material previously extracted and the extent of cultural sterilization were also noted. Vertical and horizontal dimensions were determined by using a seismograph, an EM31 terrain conductivity unit, and truck-mounted power augers capable of taking in-situ samples. The information gathered was used to

adjust the deposit dimensions established from the previous work.

From the cumulative data, tentative economic boundaries for the deposits were established. Deposits less than one metre deep, (unless of great areal extent) and aggregate resources 10 metres or more below the water table were considered uneconomical and were discounted as a regional source. However, some shallow deposits have been described as a possible resource for local use only.

Reserve Calculations

The estimated sand and gravel resources were obtained by using the F.K. Aggregate Classification System. The classification involves the analysis of data obtained from the Ontario Ministry of Transportation and Communications (M.T.C.) and the field and office methods described above. The calculated reserve figures account for local changes in quality and quantity, such as the sterilization and the depletion of the resource.

The F.K. Aggregate Classification System is shown in Table 1 (page 6) and described in Part II. The total sand and gravel reserves are shown in Table 3 (page 29) and on Maps P. 2973 to P. 2975.

Bedrock Resources

The bedrock aggregate resources were evaluated using bedrock and surficial geology maps, water well data, and aerial photograph interpretation. Areas with overburden exceeding 1.5 metres were not considered to be economically feasible for extraction, unless part of the overburden consists of extractable sand and gravel resources. This decision was based on the

quantity of available bedrock resources and current extraction practices.

The evaluation of bedrock resources was made primarily on the basis of performance and suitability data established by M.T.C. testing. The main characteristics of the bedrock formations are summarized in Appendix D. The formations are shown on Map P. 2976.

PART II - DATA PRESENTATION AND INTERPRETATION

F.K. AGGREGATE CLASSIFICATION SYSTEM

The F.K. Aggregate Classification System was developed by the Eastern Region of the Ontario Ministry of Natural Resources. The system groups sand and gravel deposits into two gradational categories of coarse and fine aggregate, and four quality categories (1-4), based on M.T.C. standards. The percent of material retained on the #4 sieve determines the coarse aggregate content. Bedrock aggregate is grouped into one gradational category (coarse aggregate) and three quality categories (1-3).

Table 1 - F.K. Aggregate Classification System

COARSE 'a'	FINE 'b'
1 - Asphalt and concrete	Asphalt and concrete
2 - Granular A, 16 mm crushed	Blending sands
3 - Granular B and C	Granular B and C
4 - Granular Fill	

Sand and Gravel Resources

Classification "1a" is coarse aggregate; "1b" is fine aggregate. Aggregate in these categories is generally acceptable for asphalt and/or concrete uses (M.T.C. Form 1002, 1003). This is the highest quality aggregate and should be protected for these purposes.

Classification "2a" includes gravel which, when processed, can meet the quality and gradational standards of M.T.C. for Granular A and 16 mm Crushed A, B (M.T.C. Form 1010). A deposit is considered a Granular A source if it contains a minimum of 35 percent gravel greater than the 5 mm sieve, and a minimum of 20 percent of the gravel larger than the 25 mm sieve. The material has quality problems which prohibit its use in asphalt or concrete mixes. This material is used as a base for asphalt or concrete pavements, as the traffic surface for secondary (gravel) roads, or as crushed aggregate for the shoulders of highways.

Classification "2b" is sand which is blended in small quantities with other sand or quarry screening in order to produce a product capable of meeting the gradational and quality specifications for asphalt or concrete.

Classifications "3a" and "3b" include aggregate commonly known as "pit run", which is normally unprocessed sand and gravel. This material is used to build the road-base to grade level in preparation for the application of Granular A (M.T.C. Form 1010).

Classification "4" includes material suitable for granular fill only. Although this material is granular in nature, it does not generally meet the foregoing specifications.

Limitations of Sand and Gravel Resources Classification

1. This classification is based on the ultimate usage of the material. Therefore, areas suitable for economic extraction have been delineated within the geological boundaries.
2. The deposits are classified by the largest proportion of

material present.

3. Some poor quality material could be beneficiated to meet higher specifications. In this way, more high quality materials may be made available.
4. Small pockets of good quality sand and gravel may occur in areas of inferior material. These small areas have not been mapped because of scale problems.
5. Quantities reported are probable reserves and not proven reserves. Therefore, the resource areas should be subjected to detailed, site-specific testing, before extraction takes place.

Bedrock Resources

For the purpose of classifying bedrock aggregate resources the P.K. Aggregate Classification System can be abbreviated to exclude fine aggregate classes and granular fill.

Classification "1a" is modified to include only those bedrock resources which are generally acceptable for both asphalt and concrete uses.

Classification "2a" bedrock resources are generally suitable for Granular A and Crushed A, B (M.T.C. Form 1010).

Classification "3a" bedrock resources have quality problems which prohibit significant volumes of this material from meeting specifications for Class "1" and Class "2" uses.

Limitations of Bedrock Resources Classification

(1) The classification is based on the ultimate uses of the material which are determined by the physical and chemical properties of the bedrock formations. Because

the formations are variable, some material within areas classed as "2a" or "3a" will meet higher specifications. Quality problems are common, and site-specific testing will be required to determine the suitability of the stone for aggregate use.

(2) Selective mining can minimize quality problems. For example, layers of alkali-reactive bedrock can in some cases be excluded from aggregate suitable for use in concrete production.

PART III - ASSESSMENT OF MINERAL AGGREGATE RESOURCES IN THE COUNTY OF LENNOX AND ADDINGTON

SAND AND GRAVEL RESOURCES

Location

The County of Lennox and Addington covers 284 071 hectares in eastern Ontario (Ontario Ministry of Municipal Affairs and Housing 1985). The county is shown on the Bancroft (31 F/4), Denbigh (31 F/3), Mazinaw Lake (31 C/14), Kaladar (31 C/11), Tichborne (31 C/10), Tweed (31 C/6), Sydenham (31 C/7), Belleville (31 C/3) and Bath (31 C/2) map sheets of the National Topographic System at a scale of 1:50 000.

Physiography

The physiography of the county has been described in a broad regional sense by Chapman and Putnam (1984). Generally, the landscape of northern Lennox and Addington County is controlled by the underlying bedrock. The topography of the Algonquin Highlands and Georgian Bay Fringe Physiographic Regions is often rugged and characterized by thinly till-covered, rounded rock knobs and ridges. Outcrops of bare rock are common. Areas of thicker till have a smoother, moulded appearance and occasionally are drumlinized. The Dummer Moraines, typified by a rough, hummocky, stony-bouldery landscape, separates the northern part of the county from the southern. The southern part,or the Napanee Plain, is a flat to undulating limestone plain with a thin and discontinuous cover of glacial sediments.

Quaternary Geology

The current landscape and distribution of surficial materials are a result of events which occurred during the Pleistocene

Epoch, informally known as the "Great Ice Age". The continental ice sheet spread from Northern Quebec and Kewatin into the basins of the Great Lakes and joined together to cover all of southern Ontario. The extent of the ice and the positions of its lobate margin underwent numerous fluctuations during deglaciation until approximately 10 000 years ago when its direct effect on southern Ontario was dissipated.

The particular glacial history and surficial geology of the County of Lennox and Addington has been described in varying degrees by Barnett (1983), Dreimanis (1977), Finamore and Courtney (1982), Gadd (1980), Henderson (1972), Leyland (1982a,b), Leyland and Mihychuk (1983), Leyland and Russell (1983, 1984), Mirynech (1962), Terasmae (1980) and Vreeken (1981). In brief, there were two major ice advances, one from the northeast and one from the southeast. Striations, drumlins and ice-marginal features mark the direction of ice movement.

As the ice mass advanced, it incorporated debris from the underlying soil and bedrock and began to crush it. This debris, a mixture of stones, sand, silt and clay called till, was deposited over large sections of the county as till plains, ridges and moraines. In northern Lennox and Addington, the texture of the till ranges from a stony and gritty silty sand to sand (Finamore and Courtney 1982). In general, where the till is thin and overlying bedrock, the texture is loose stony sand. In drumlins and drumlinoid ridges, the till is often compact and contains 5 to 10 percent stones. Sand lenses, layers and stringers are common in the till exposures (Barnett and Leyland 1980). In southern Lennox and Addington, the till plain has been drumlinized and the texture of the material ranges from a gritty silty sand to a sandy

silt, moderately stony and compact (Leyland and Mihychuk 1983). Till occurring within the Dummer Moraine Physiographic Region is extremely stony and contains angular clasts ranging in size from pebbles to large boulders (Leyland and Mihychuk 1983). The material is occasionally observed to grade into poorly sorted sand and gravel, probably indicating that the deposit was 'washed' by glacial meltwater (Leyland and Russell 1984).

Deglaciation was characterized by a general northward melting back of the ice mass although some evidence of a local ice readvance from the southeast out of the St. Lawrence River has been found (Leyland 1982a). Glaciofluvial and glaciolacustrine deposits provide the bulk of sand and gravel reserves in the county. For example, gaps or tunnels under the ice filled up with glaciofluvial debris forming eskers such as the Codrington Esker (Chapman and Putnam 1984) which extends through Tamworth and Beaver Lake. Esker-fans at Denbigh, Copeland Lake, Slate Falls and Vennachar indicate that the meltwaters emptied directly into a lake. In terms of aggregate potential, the eskers and associated outwash are desirable sources of good quality sand and gravel. Other significant glaciofluvial features include the outwash deposits along Wilton Creek and the Napanee River. Generally, the coarse-textured outwash occurs in association with eskers. Fine-textured outwash occurs as isolated remnants along bedrock valleys (Leyland and Mihychuk 1983). Fine-textured or sandy outwash occurs along the Salmon River Valley.

As the ice melted back, water collected in the Lake Ontario basin forming glacial Lake Iroquois. At least six lake levels existed in the general area and their positions are marked by

numerous, small beach ridges. Glaciolacustrine silts and clays occur widely. Drilling in Abinger Township, along Kilpecker Creek, revealed 4 to 14 metres of fine sand overlying up to 20 metres of varved clay. The glaciolacustrine material is generally too fine to meet high quality aggregate specifications.

As the ice retreated further northward, the glacial lakes drained. Post-glacial deposits include some modern alluvium and numerous bogs and swamps. This recent material, however, has little potential for aggregate use.

BEDROCK RESOURCES

Bedrock Geology

Lennox and Addington is underlain by metamorphic and plutonic Precambrian rocks of the Grenville Province, overlain in turn by a succession of sandstones, limestones and shales of Paleozoic age. Paleozoic age rocks occur throughout the southern part of the county and as outliers within areas of predominantly Precambrian rocks. Drift cover is generally thin throughout the southern half of the county.

The rock descriptions and stratigraphy used in this report are those of Williams and Rae (1983). The distribution of rock types is outlined on maps by Carson (1981 a, b, c; 1982).

TABLE 2: BEDROCK STRATIGRAPHY OF THE COUNTY OF LENNOX AND ADDINGTON*

AGE	FORMATION
Paleozoic	
Middle Ordovician	Verulam Formation Bobcaygeon Formation Gull River Formation Shadow Lake Formation
Unconformity	
Precambrian	Metamorphic and Igneous rocks

*modified after Williams and Rae (1983)

The Precambrian rocks include metamorphosed volcanic rocks, clastic and chemical metasediments, and plutonic rocks. Although many of the Precambrian rock types would make sound aggregate, they are not generally used for this purpose, because of the high cost of extraction and processing.

The sandy to shaly Shadow Lake Formation is the oldest Paleozoic formation in the area. Two members have been identified: a lower, sandy member and an upper, dolomitic and shaly member. The Shadow Lake Formation is generally very friable and not a good aggregate source.

The Gull River Formation consists of interbedded silty dolostone, lithographic to fine-crystalline limestone, shale and fine-grained calcareous quartz sandstone. The formation can be subdivided into two members. The Lower Member is quarried for aggregate, but contains some silty dolostone beds which produce unsound aggregate, and dolomitic limestone beds which are alkali reactive. The Upper Member is mainly limestone, much of which is suitable for all aggregate applications. Some alkali-reactive beds and some chert nodules occur.

Limestone of the overlying Bobcaygeon Formation is distinguished chemically from the Upper Gull River Formation by an increase in acid insolubles and a decrease in CaO. The Bobcaygeon Formation consists of interbedded calcarenite and sublithographic to fine-crystalline limestone. Two members have been mapped. The Upper Member is typically coarse-grained limestone containing less shale than the Lower Member. The Bobcaygeon Formation contains finely disseminated chert which renders the stone unsuitable for concrete because of alkali-silica reactions.

The overlying Verulam Formation consists of interbedded biocalcarenite, calcarenite, sublithographic to fine-crystalline limestone and calcareous shale. The formation is very thin to medium bedded. Although generally unsuitable for high quality aggregate, because of the shale content, the Verulam Formation is preferred for the production of portland cement.

Summary of Bedrock Resources

The Paleozoic bedrock resources of Lennox and Addington occur exclusively within the southern portion of the county, south of King's Highway 7. The bedrock is thinly drift covered and substantial volumes of aggregate may be available. However, probable reserves of bedrock aggregate were not calculated because of the lack of data regarding formation thicknesses.

Bedrock which may produce aggregate suitable for Class "1" uses is found within the Upper Member of the Gull River Formation. The formation is thinly drift covered throughout much of the southeastern corner of the county. Significant reserves occur in Ernestown, Camden East, Richmond and North Fredericksburgh Townships. Smaller reserves of Class "1" bedrock aggregate are also found in Sheffield Township.

Bedrock suitable for Class "2" uses occurs within the Gull River and Bobcaygeon Formations. Extensive areas of these rocks occur within several townships including Ernestown, North and South Fredericksburgh, Camden East and Richmond.

Bedrock suitable for Class "3" uses is provided by the Verulam Formation. Substantial reserves of Class "3" bedrock aggregate occur within Amherst Island, Ernestown, South and North Fredericksburgh, and Richmond Townships.

RECOMMENDATIONS

1. With processing, portions of the Class "3" sand and gravel deposits can be upgraded to meet higher specifications. These areas may be useful where Class "1" and "2" materials are not delineated.
2. The sand and gravel deposits designated as Class "1" and Class "2" under the F.K. Aggregate Classification System should be protected for future use under the Extraction Industry Category in municipal planning documents. Portions of Class "3" sand and gravel should be protected after consultation between the county, municipality and the Ontario Ministry of Natural Resources. This is extremely important for the townships south of King's Highway 7.
3. There is an abundance of small glaciofluvial deposits and ancient beach ridges within the county which are capable of supplying aggregate for local needs. Extraction and/or protection should be permitted under the Rural Category.
4. Many of the areas delineated as Class "1a" under the F.K. Aggregate Classification System can be used to produce a Class "2a" product. This is an acceptable use if some of the material is protected for future use as Class "1" sand and gravel.

Enquiries regarding the Mineral Aggregate Resources Inventory of the County of Lennox and Addington should be directed to the Eastern Region, Ontario Ministry of Natural Resources, at P.O. Box 2002, Concession Road, Kemptville, Ontario, K0G 1J0, [Tel. (613) 258-8234].

SAND AND GRAVEL RESOURCES SUMMARY BY TOWNSHIP

Abinger Township

Abinger Township has the largest sand and gravel resources within the County of Lennox and Addington. Approximately 47.53 million cubic metres of aggregate are available, although much of the material will meet only Class "3" specifications.

The largest sand and gravel reserves are found within the glaciofluvial and glaciolacustrine deposits along King's Highway 41 in the northwestern portion of the township. An estimated 33.19 million cubic metres of material are available. The deposits, which in some locations overlie up to 34 metres of clay, contain all the Class "1" material delineated within the township. Portions of the deposits which are delineated as Class "3" will meet Class "1" and "2" specifications with processing. These portions are too small to be accurately mapped and have been included within the larger Class "3" category.

The second largest reserve consists of the glaciofluvial deposits around Long Mallory and Brooks Lakes. An estimated 3.89 million cubic metres of material are available. A few sections of these deposits will meet higher specifications, but these are limited and have been included within the Class "3" volumes.

The third largest reserve consists of the glaciofluvial deposits around Buckshot Lake. Approximately 3.33 million cubic metres of Class "3a" material are available. Sections of these deposits contain greater than 30 percent stone, however, the gravel is too fine (80 percent being less than 2.5 centimetres) to render a satisfactory crushed product.

The fourth largest reserve is the glaciofluvial deposits

around Finch and Little Finch Lakes and Cotton Creek. These sand deposits will meet only Class "3b" specifications. Approximately 2.92 million cubic metres of material remain.

There are four other reserves within the township which contain significant sand and gravel. These contain 4.20 million cubic metres, or less than 9 percent of the township's available material. Sections of the deposits will meet higher specifications. However, these sections are small and limited and represent only a minor proportion of the total available material.

Adolphustown Township

There are very few aggregate reserves in Adolphustown Township. Many of the possible reserve areas which have been delineated are shallow and will not support any large demands. Although they have been designated as Class "4", higher quality material may be available.

A series of wind-modified glaciofluvial deposits northeast of Watercombe will meet only Class "3" specifications. There are approximately 0.10 million cubic metres of material remaining.

Amherst Island Township

There are few sand and gravel reserves on Amherst Island. There are four small ancient beach ridges, but these are poorly formed and can be used only for fill. High quality aggregate must be transported to the island or derived from the underlying Paleozoic rocks.

Anglesea Township

Anglesea Township contains 3.82 million cubic metres of aggregate. The largest aggregate reserve is located on the boundary between the Counties of Frontenac and Lennox and

Addington. An estimated 3.51 million cubic metres of material remain. Extensive areas have been built upon or have been excavated. An assessment of these ice-marginal deposits concluded that 1.20 million cubic metres of Class "1" and 2.31 million cubic metres of Class "3" material remain. Some of the Class "1" material can be crushed to produce an acceptable Granular "A" product.

The deposits around Skootamatta Lake are suitable only for local needs. These shallow deposits contain an estimated 0.31 million cubic metres of material.

Ashby Township

There are 6.41 million cubic metres of aggregate available within Ashby Township. This material will meet only Class "3" specifications.

The largest sand and gravel reserve consists of the glaciofluvial deposits around Trout and Spring Lakes. An estimated 4.13 million cubic metres of Class "3" material remain within these deposits. A high fines content limits the deposits' classifications.

There is another aggregate source northwest of Weslemkoon Lake. Approximately 1.95 million cubic metres of Class "3" material remain. The presence of very fine sand and silt limits the deposits' classification.

The other deposits within the township have only minor reserves; approximately 0.33 million cubic metres of material remain.

Camden East Township

There are 2.97 million cubic metres of aggregate available

within Camden East Township. The material will meet only Class "3" specifications.

The largest deposit within the township is the Pennells Hill esker. Previous extraction and development has reduced the probable reserves. In addition, there are severe quality problems presented by the large amounts of deleterious aggregate. An estimated 0.98 million cubic metres of Class "3a" sand and gravel remain.

The second largest sand and gravel reserve consists of the glaciofluvial deposits around Reidville. Much of the material has been excavated or built upon and the remaining material has quality problems which limit the possible uses. Approximately 0.66 million cubic metres of aggregate remain.

The third largest reserve occurs north of Colebrook. Although these sand and gravel deposits have been extensively excavated, substantial reserves remain. If processed, the material may meet Class "1" and Class "2" specifications. There are 0.59 million cubic metres of Class "3" material remaining.

The remaining aggregate reserves occur in glaciofluvial deposits scattered throughout the township. These deposits are too small, both in areal extent and depth, to meet any large construction demands. They are, though, important local sources of material. An estimated 0.74 million cubic metres of material are available.

Denbigh Township

Denbigh Township has the second largest reserves of sand and gravel in the county. Approximately 46.94 million cubic metres of material are available.

The largest aggregate reserve is the glaciofluvial deposits along Henderson Creek within the northeastern portion of the township. An estimated 11.98 million cubic metres of material are available for extraction and/or protection. Abrupt gradational changes limit the deposits' possible uses. Approximately 11.81 million cubic metres of Class "3" material remain. Also, 0.17 million cubic metres of Class "1" material occur within the esker ridge south of Little Green Lake.

The second largest aggregate reserve is the glaciofluvial deposits north of Glenfield. An estimated 5.70 million cubic metres of material remain. The excess of fine sand and silt limits the aggregate's possible uses. There are approximately 5.55 million cubic metres of Class "3" and 0.15 million cubic metres of Class "1" material remaining.

The third largest reserve consists of the glaciofluvial deposits at Slate Falls; approximately 3.55 million cubic metres of material remain. The esker portion of the deposit contains Class "1" material totalling 0.75 million cubic metres. Testing has established that this esker ridge has a coarse segment greater than 35 percent of the total volume. The aggregate can be crushed to produce a Class "2a" product. The outwash/fan portion of the deposit is limited by abrupt gradational changes. Some vertical sections will meet Class "1" and "2" specifications. However, the presence of fine sand and silt layers reduces the classification to "3". Approximately 2.80 million cubic metres of material are available.

The majority of the glaciofluvial deposits north of Vennachar will meet only Class "3" specifications. An estimated 2.25 million cubic metres of material meet Class "3b" specifications; 0.72 million cubic metres meet Class "1" requirements. A small esker ridge adjacent to Glenfield Creek provides all of the Class "1" material.

The esker/fan deposits south of Copeland Lake have significant amounts of Class "1" material remaining. The southern portion of the deposit will, because of extreme gradational changes and the presence of silt layers, meet only Class "3" specifications. The Class "1" material, 1.21 million cubic metres, occurs within the esker ridge in the northern portion of the deposit. The esker material will, if crushed, provide an acceptable Granular "A" product. The glaciofluvial deposits north of Copeland Lake contain 0.16 million cubic metres of Class "1" material.

The majority of the glaciofluvial deposits along Steins Creek, west of Denbigh, will meet only Class "3" specifications. An estimated 2.29 million cubic metres of Class "3" material remain. The esker portion of the deposit contains all of the Class "1" material, approximately 0.60 million cubic metres. Although large sections of the esker are in the "b" category of the F.K. Aggregate Classification System, some of the aggregate can be crushed to produce an acceptable Granular "A" product.

The glaciofluvial deposit south of Ferguson Corners has a small section which will meet Class "1" specifications. This

material has been extensively excavated and built upon. Only 30 thousand cubic metres of material remain. The remaining material, 2.86 million cubic metres, will meet Class "3" specifications.

The only other two significant sources of sand and gravel within the township are the glaciofluvial deposits north of Blakely Lake and east of Denbigh. Investigation of the deposit north of Blakely Lake indicated 2 to 4 metres of coarse material overlying 4 to 6 metres of fine sand and gravel. The deposit has been conditionally designated as Class "3a" with the stipulation that higher quality material may be available with processing. There are 1.22 million cubic metres of material remaining. The deposit east of Denbigh has 2.61 million cubic metres of material remaining. Sections of this deposit may meet Class "1" and "2" specifications with processing. The deposit has been delineated as Class "3" with the stipulation that higher quality material may be available.

Most of the remainder of the deposits within the township will meet only Class "3" specifications. Approximately 11.61 million cubic metres of material remains.

Effingham Township

There are 7.06 million cubic metres of material available within Effingham Township. Over 90 percent of the available material (6.57 million cubic metres) is located within two areas.

The larger sand and gravel source consists of the glaciofluvial deposit in the northeastern portion of the township, along King's Highway 41. An estimated 3.92 million cubic metres of material remain. The deposit, which is up to 30 metres in

depth, has been delineated as Class "3". The presence of silt, very fine sand, and till layers are limiting factors. Higher quality material can be made available with processing.

The glaciofluvial deposit southwest of Weslemkoon Lake is the second largest source within the township. An estimated 2.65 million cubic metres of material remain; 1.30 million cubic metres meet Class "3" specifications and 1.35 million cubic metres meet Class "1" specifications. Sections of this deposit can be crushed to produce a satisfactory Granular "A" product.

The remaining aggregate reserves are scattered throughout the township in small ridges. An estimated 0.49 million cubic metres of material remain.

Ernestown Township

There are 2.25 million cubic metres of aggregate available within Ernestown Township. The material will meet only Class "3" specifications.

The largest aggregate reserve is the spillway deposit along Wilton Creek. These sand deposits have been extensively excavated and built upon. There are abrupt gradational changes within the deposit; silt and very fine sand layers occur above and below high quality (Class "1") sands. An estimated 2.17 million cubic metres of Class "3" material are available. With processing, this material may meet Class "1" and Class "2" specifications.

Additional reserves occur west of Bath. These ancient beach ridges will meet only Class "3" specifications. Approximately 80 thousand cubic metres of material remain.

There are many other deposits scattered throughout the township. These deposits are poorly formed and do not have any

extensive aggregate reserves. Although designated as Class "4", higher quality material may be available for local uses.

Kaladar Township

Kaladar Township has the third largest sand and gravel reserves within the County of Lennox and Addington. There are 38.58 million cubic metres of material available for extraction and/or protection. Four sources account for 90 percent (34.59 million cubic metres) of the available material.

The largest aggregate source occurs east of the Skootamatta River, near Flinton. This ice-marginal/spillway deposit contains 15.71 million cubic metres of material. The southwestern portion of the deposit has steep sides and resembles an esker. This segment of the deposit contains all of the Class "1" material; an estimated 1.36 million cubic metres. Sections of the deposit can be crushed to produce a satisfactory Granular "A" product.

The second largest aggregate source consists of the glaciofluvial deposits around Northbrook. Although many of the deposits have been built upon, 9.36 million cubic metres of material remain. These deposits are primarily sand and have been classified as "3b".

The third largest source is the glaciofluvial deposits at Flinton Corner. The deposits have variable depths and the materials are characterized by abrupt gradational changes. These sand deposits are Class "3b" and have probable reserves of 6.32 million cubic metres. Small sections of these deposits may meet Class "1" and Class "2" specifications with processing.

The fourth largest aggregate source occurs near the Anglesea Township border. These ice-marginal/spillway deposits have

probable reserves of 3.20 million cubic metres. Sections may meet Class "1" and Class "2" specifications with processing. The majority of the material, though, will meet only Class "3" requirements. A total of 1.58 million cubic metres of Class "3a" and 1.62 million cubic metres of Class "3b" sand and gravel remain.

The remaining material, 3.99 million cubic metres, occurs in small ridges which will support only modest demands. Exceptions are the glaciofluvial ridges south of Flinton Corner, east of King's Highway 41. Although these deposits are small, sections of them meet Class "1" specifications.

North Fredericksburgh Township

There are only minor amounts of sand and gravel available within North Fredericksburgh Township. An estimated 0.48 million cubic metres of material remain.

The only deposits with significant reserves occur east of Mohawk Bay. These wind-altered deposits are shallow and will meet only Class "3" specifications. There are approximately 0.48 million cubic metres of material remaining.

Many additional deposits are located throughout the township. These deposits are shallow and are generally not viable resources.

Richmond Township

There are 2.89 million cubic metres of aggregate available within Richmond Township. The material will meet only Class "3" specifications because of quality problems.

The largest reserves occur in the Pennells Hill and Marlbank eskers. The materials within these eskers have severe quality

problems. The presence of stones from the Shadow Lake Formation (a silty-sandstone) limits the possible uses of the aggregate. Consequently, the material, although coarse enough to be crushed, will meet only Class "3" specifications. An estimated 1.75 million cubic metres remain.

The second largest reserve occurs in the grouping of ancient beach ridges in the Mount Pleasant area. These ridges contain approximately 0.51 million cubic metres of Class "3a" and "3b" material.

The only other significant deposits within the township are the spillway deposits around Forest Mills. An estimated 0.37 million cubic metres of Class "3" material remain.

The remaining aggregate deposits are small ancient beach ridges which will meet only Class "3" specifications. These ridges will support only local needs; approximately 0.26 million cubic metres of material remain.

Sheffield Township

There are 5.56 million cubic metres of material available within Sheffield Township. Much of this material occurs within the esker and esker-like ridges which traverse the township. Extensive amounts of the material, notably around Tamworth, has been previously excavated. Testing has also confirmed that the quality of the material within the northern ridges is significantly different than in the southern ridges. North of Beaver Lake, along County Road 15, much of the material will meet Class "1" specifications. There are 0.67 million cubic metres of Class "1" and 0.41 million cubic metres of Class "3" sand and gravel remaining within these ridges. South and west of Beaver

Lake, the majority of the material will meet only Class "3" specifications. The presence of stone from the underlying Shadow Lake Formation (a silty-sandstone) has limited the material's possible uses. A total of 2.99 million cubic metres of material remain.

The remaining aggregate reserves, 1.49 million cubic metres, occur in small ridges scattered throughout the township. Again, the presence of the silty-sandstone limits the material's possible uses.

South Fredericksburgh Township

There are only minor amounts of sand and gravel available within South Fredericksburgh Township. An estimated 0.32 million cubic metres of Class "3" material remain.

The largest aggregate reserve occurs near Galts Corner. These shallow, ancient beach ridges are poorly developed and will meet only Class "3" specifications. Approximately 0.21 million cubic metres of material remain.

The only other area of appreciable reserves occurs in shallow beach ridges east of Hay Bay. There are 0.11 million cubic metres of material remaining.

TABLE 3. CLASSIFIED AGGREGATE - SAND AND GRAVEL PROBABLE RESERVES (Million Cubic Metres)

TOWNSHIP	F.K. AGGREGATE CLASSIFICATION SYSTEM						
	1a	1b	2a	2b	3a	3b	TOTAL
Abinger	0.92	1.09	-	-	10.00	35.52	47.53
Adolphustown	-	-	-	-	-	0.10	0.10
Amherst Island	-	-	-	-	-	-	-
Anglesea	0.66	0.54	-	-	1.45	1.17	3.82
Ashby	-	-	-	-	1.35	5.06	6.41
Camden East	-	-	-	-	2.06	0.91	2.97
Denbigh	2.00	1.79	-	-	4.69	38.46	46.94
Effingham	0.35	1.00	-	-	2.61	3.10	7.06
Ernestown	-	-	-	-	-	2.25	2.25
Kaladar	0.35	1.10	-	-	2.36	34.77	38.58
N. Fredericksburgh	-	-	-	-	-	0.48	0.48
Richmond	-	-	-	-	2.28	0.61	2.89
Sheffield	0.18	0.49	-	-	4.42	0.47	5.56
S. Fredericksburgh	-	-	-	-	0.32	-	0.32
TOTAL	4.46	6.01	-	-	31.54	122.90	164.91

TABLE 4 - SAND AND GRAVEL RESOURCES - ABINGER TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
Glaciofluvial and glaciolacustrine assemblage along King's Highway 41, Mississippi River, Kilpecker Creek and Louse Creek	-	-	911.51	469.29	73.12	2-14	33 190 000	1a 920 000 1b 1 090 000 3a 1 520 000 3b 29 660 000
Glaciofluvial deposits east of Mazinaw Lake	1-2	8-20	127.45	81.27	-	2-10	1 760 000	3a 1 760 000
Glaciofluvial deposits around Mallory Lake, Elbow Lake, Little Mud Lake	West-east Range 18,19 Con. 8-12	19-26	39.73	13.42	-	1-6	1 410 000	3a 1 350 000 3b 60 000
Glaciofluvial deposits around Long Mallory Lake and Brooks Lake	6-8	4-13	136.23	27.61	1.20	2-8	3 890 000	3a 1 810 000 3b 2 080 000
Glaciofluvial deposits around Buckshot Lake	1-3	1-5	121.52	-	26.16	3-06	3 330 000	3a 3 330 000
4 glaciofluvial deposits northeast of Winter Road	13-14	11-16	5.15	1.03	-	1-4	120 000	3a 80 000 3b 40 000
Glaciofluvial deposits around Finch Lake, Little Finch Lake and Cotton Creek	14-16	1-7	44.12	2.84	4.97	1-10	2 920 000	3b 2 920 000
Glaciofluvial deposits north of Vennacher	16	9-15	22.70	-	1.77	2-10	910 000	3a 150 000 3b 760 000

TABLE 5 - SAND AND GRAVEL RESOURCES - ADOLPHUSTOWN TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
4 ancient beach ridges	3	24-30	9.55	9.55	-	-	-	-
4 ancient beach ridges	1	26-34	10.58	10.58	-	-	-	-
3 glaciofluvial deposits	5	16-22	17.55	3.10	9.42	1-4	100 000	3b 100 000
2 fill deposits	4-5	14-15	6.45	6.45	-	-	-	-
5 ancient beach ridges	2-3	13-21	22.19	22.19	-	-	-	-
4 ancient beach ridges	1	13-22	21.93	21.93	-	-	-	-

TABLE 6 - SAND AND GRAVEL RESOURCES - AMHERST ISLAND TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
4 ancient beach ridges	-	-	10.84	10.84	-	-	-	-

TABLE 7 - SAND AND GRAVEL RESOURCES - ANGLESEA TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
Glaciofluvial deposits on the borders of the Counties of Lennox and Addington, and Frontenac	Range west 1-17	-	139.59	4.39	53.12	1-10	3 510 000	1a 660 000 1b 540 000 3a 1 290 000 3b 1 020 000
Glaciofluvial deposits around Skootamatta Lake	11-12	5-7	38.44	16.51	11.85	1-5	310 000	3a 160 000 3b 150 000

TABLE 8 - SAND AND GRAVEL RESOURCES - ASHBY TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
15 glaciofluvial deposits around Trout and Spring Lakes	14-16	-	138.80	65.79	5.20	2-8	4 130 000	3a 540 000 3b 3 590 000
Glaciofluvial deposit southeast of Ashby Lake	4	2-4	45.67	29.67	6.08	2-6	210 000	3b 210 000
2 glaciofluvial deposits east of Smith Lake	1	7-10	5.42	-	-	2-5	120 000	3b 120 000
12 glaciofluvial deposits north and northwest of Weslemkoon Lake	5-8	22-34	143.45	93.91	.259	2-8	1 950 000	3a 600 000 3b 1 350 000

TABLE 9 - SAND AND GRAVEL RESOURCES - CAMDEN EAST TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
Pennells Hill esker	9	1-25	94.94	13.93	57.19	1-5	980 000	3a 980 000
15 glaciofluvial deposits around Reidville	8	16-30	65.79	10.32	28.49	1-5	660 000	3a 660 000
4 glaciofluvial deposits	7-8	34-37	4.90	1.29	3.61	1-3	-	-
6 glaciofluvial deposits	9	36-38	9.55	-	1.34	1-3	180 000	3a 180 000
5 glaciofluvial deposits	7-8	45-48	13.16	-	1.88	1-4	200 000	3a 200 000
10 fill deposits	5	40-47	18.32	18.32	-	-	-	-
6 glaciofluvial deposits	6	25-36	28.38	9.80	18.14	1-4	10 000	3a 10 000
5 fill deposits	6-7	17-25	5.16	5.16	-	-	-	-
4 fill deposits	5	19-24	7.48	7.48	-	-	-	-
7 fill deposits	4	30-39	22.70	22.70	-	-	-	-
4 fill deposits	3-4	33-36	11.61	11.61	-	-	-	-
5 fill deposits	2-3	10-15	10.06	10.06	-	-	-	-
3 fill deposits	2	8-9	3.61	3.61	-	-	-	-
2 fill deposits	4-5	1	4.64	4.64	-	-	-	-
3 glaciofluvial deposits north of Colebrook	3	42-44	52.11	4.64	29.92	1-6	590 000	3b 590 000

(Continued)

TABLE 9 - SAND AND GRAVEL RESOURCES - CAMDEN EAST TOWNSHIP (Cont'd)

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
4 ancient beach ridges	2	25-33	8.00	3.87	2.18	1-4	30 000	3a 30 000
9 spillway deposits	1	24-35	36.89	24.25	12.24	1-4	10 000	3b 10 000
3 spillway deposits	1-2	16-21	13.94	3.87	8.37	1-5	40 000	3b 40 000
10 spillway deposits	1	10-14	16.00	8.26	4.99	1-5	60 000	3b 60 000
4 spillway deposits	1	2-9	14.71	5.42	3.44	2-8	210 000	3b 210 000
3 fill deposits	1	41-47	5.42	5.42	-	-	-	-

TABLE 10 - SAND AND GRAVEL RESOURCES - DENBIGH TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
7 glaciofluvial deposits along Hydes Creek	15-16	1-4	26.31	-	1.88	2-6	760 000	3b 760 000
17 glaciofluvial deposits along Henderson Creek	13-16	6-14	144.23	12.64	1.22	2-18	11 980 000	1a 100 000 1b 70 000 3a 690 000 3b 11 120 000
12 glaciofluvial deposits north of Slater Lake	15-16	15-19	53.14	7.22	3.57	2-8	1 960 000	3a 830 000 3b 1 130 000
4 glaciofluvial deposits north of Slate Falls	13-14	15-16	21.93	-	6.02	1-6	680 000	3a 120 000 3b 560 000
10 glaciofluvial deposits at Slate Falls	11-12	14-19	55.72	6.71	9.97	2-20	3 550 000	1a 400 000 1b 350 000 3b 2 800 000
6 glaciofluvial deposits along Hydes Creek	13-14	5,6	8.26	-	2.58	1-4	160 000	3b 160 000
4 glaciofluvial deposits	12	5-8	11.09	-	1.03	1-4	550 000	3b 550 000
9 glaciofluvial deposits	10-11	9-13	54.63	-	10.43	2-18	2 920 000	3b 2 920 000
4 glaciofluvial deposits east of Denbigh	9	12-15	28.13	-	2.97	2-8	2 610 000	3a 1 030 000 3b 1 580 000
13 glaciofluvial deposits north of Denbigh Lake	8-9	18-22	41.02	2.84	15.06	2-14	1 520 000	3b 1 520 000

(Continued)

TABLE 10 - SAND AND GRAVEL RESOURCES - DENBIGH TOWNSHIP (Cont'd)

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
18 glaciofluvial deposits west of Denbigh	8-9	Range east 21-25 Lot 23	67.09	1.29	14.49	3-14	2 890 000	1a 180 000 1b 420 000 3b 2 290 000
Glaciofluvial deposit north of Blakely Lake	11	33-34	16.00	-	-	2-8	1 220 000	3a 1 220 000
4 glaciofluvial deposits east of Denbigh Lake	6,7	14-20	22.19	10.58	-	3-12	1 030 000	3b 1 030 000
Glaciofluvial deposits east of Leatherroot Mountain	10	1-2	41.02	41.02	-	-	-	-
9 glaciofluvial deposits around Crooked and Outer Duck Lakes	Range east & west 13-17	-	35.35	11.61	6.75	2-6	440 000	3b 440 000
3 glaciofluvial deposits north of Copeland Lake	4-5	13-15	10.06	-	-	2-8	440 000	1a 90 000 1b 70 000 3b 280 000
Glaciofluvial and glaciolacustrine deposits at Ferguson Corners	Range east & west 1-10	-	227.56	128.24	31.30	2-10	2 890 000	1a 20 000 1b 10 000 3a 270 000 3b 2 590 000
5 glaciofluvial deposits south of Copeland Lake, east of Vennachar Junction	2-3	15-19	59.08	1.29	16.94	2-13	2 670 000	1a 750 000 1b 460 000 3b 1 460 000

(Continued)

TABLE 10 - SAND AND GRAVEL RESOURCES - DENBIGH TOWNSHIP (Cont'd)

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
21 glaciofluvial and glaciolacustrine ridges north of Vennacher	1-3	9-15	92.89	-	18.14	2-10	2 970 000	1a 390 000 1b 330 000 3b 2 250 000
28 glaciolacustrine deposits at and north of Glenfield	2-7	1-6	95.77	5.22	11.43	2-23	5 700 000	1a 70 000 1b 80 000 3a 530 000 3b 5 020 000

TABLE 11 - SAND AND GRAVEL RESOURCES - EFFINGHAM TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
Weslemkoon glacio-fluvial ridge	12-13	26-34	85.13	23.48	26.74	7-12	2 650 000	1a 350 000 1b 1 000 000 3a 550 000 3b 750 000
6 glaciofluvial ridges south and west of Effingham Lake	-	-	12.90	3.35	0.10	1-5	350 000	3a 350 000
4 glaciofluvial deposits	8	5-8	8.77	3.61	-	1-5	140 000	3a 90 000 3b 50 000
Glaciofluvial deposit along King's Highway 41, Mississippi River and Donnelly Creek	-	-	189.38	112.23	23.03	2-30	3 920 000	3a 1 620 000 3b 2 300 000

TABLE 12 - SAND AND GRAVEL RESOURCES - ERNESTOWN TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
7 ancient beaches & glaciofluvial deposits, west portion of Bath Municipal limits	1	-	14.45	10.32	0.83	1-4	80 000	3b 80 000
3 ancient beach ridges	2	1-6	12.64	12.64	-	-	-	-
5 ancient beach ridges	2	8-13	24.25	24.25	-	-	-	-
4 ancient beach ridges	2	15-24	17.80	17.80	-	-	-	-
4 ancient beach ridges	3	11-17	16.77	16.77	-	-	-	-
3 ancient beach ridges	3	1-4	12.90	12.90	-	-	-	-
7 fill deposits	4	2-12	23.74	23.74	-	-	-	-
4 fill deposits	5-6	3-9	5.93	5.93	-	-	-	-
4 deposits	5	12-14	12.12	4.90	6.22	1-5	-	-
4 ancient beach ridges	6-7	26-31	7.58	4.64	2.94	1-3	-	-
Spillway deposits along Wilton Creek	5-7	14-21	233.77	65.27	92.15	1-5	2 170 000	3b 2 170 000

TABLE 13 - SAND AND GRAVEL RESOURCES - KALADAR TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
7 glaciofluvial deposits	7-9	9-12	32.77	19.35	8.05	1-5	140 000	3b 140 000
4 glaciofluvial deposits	6-8	12-13	14.19	7.48	5.03	1-6	50 000	3b 50 000
10 glaciofluvial deposits south of Flinton Corner	6-8	16-19	27.61	15.74	6.46	1-5	230 000	1a 40 000 1b 50 000 3b 140 000
16 glaciofluvial deposits at Flinton Corner	5-7	19-25	315.52	36.12	56.70	1-10	6 320 000	3b 6 320 000
10 glaciofluvial deposits near Northbrook	6-11	24-27	356.29	47.99	81.10	1-10	9 360 000	3a 780 000 3b 8 580 000
7 glaciofluvial deposits	5	25-30	27.09	9.80	3.58	1-6	380 000	3b 380 000
5 glaciofluvial deposits	4-5	23-24	18.91	1.81	5.17	1-8	1 270 000	3b 1 270 000
6 glaciofluvial deposits	3-4	22-24	16.25	-	2.78	1-4	380 000	3b 380 000
26 glaciofluvial deposits	1-3	19-24	93.14	11.61	15.73	1-8	1 540 000	3b 1 540 000
Large glaciofluvial deposit near Flinton	1-5	10-23	529.16	35.09	155.53	2-15	15 710 000	1a 310 000 1b 1 050 000 3b 14 350 000
2 glaciofluvial deposits on Kaladar and Anglesea Township borders	7-8	28-32	124.61	2.84	29.24	1-10	3 200 000	3a 1 580 000 3b 1 620 000

TABLE 14 - SAND AND GRAVEL RESOURCES - NORTH FREDERICKSBURGH TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
3 fill deposits	4	24-27	8.00	8.00	-	-	-	-
5 fill deposits	4	16 Gore -21	17.03	17.03	-	-	-	-
5 fill deposits	5-6	21-25	15.22	15.22	-	-	-	-
5 fill deposits	6	19-23	13.67	13.67	-	-	-	-
4 fill deposits	5	15-17	9.03	9.03	-	-	-	-
3 fill deposits	7	11-18	98.81	98.81	-	-	-	-
3 fill deposits	3-4	8-10	7.22	7.22	-	-	-	-
3 fill deposits	4	5-6	5.16	5.16	-	-	-	-
2 fill deposits	2	5-9	10.06	10.06	-	-	-	-
3 fill deposits	3 Additional Concessions 4-5	1-2 1-2	12.38	12.38	-	-	-	-
7 glaciofluvial deposits	Additional Concession 5	3-5	31.99	-	15.18	1-4	480 000	3b 480 000
7 ancient beach ridges	Additional Concessions 4-5	9-13	27.35	27.35	-	-	-	-
3 fill deposits	7	24-28	14.19	14.19				

TABLE 15 - SAND AND GRAVEL RESOURCES - RICHMOND TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
9 ancient beach ridges	1	2-11	31.48	28.38	1.24	1-3	50 000	3a 50 000
2 glaciofluvial deposits	1	16-17	14.96	-	8.94	1-5	120 000	3a 120 000
7 ancient beach ridges	2	1-13	27.34	18.83	8.51	1-3	-	-
8 ancient beach ridges	3	1-13	42.31	8.00	16.07	1-5	510 000	3a 360 000 3b 150 000
2 ancient beach ridges	3	19-21	5.42	1.81	2.03	1-4	30 000	3b 30 000
3 ancient beach ridges	2	17-19	10.32	7.22	0.81	1-4	50 000	3b 50 000
3 ancient beach ridges	1-2	23-17	5.42	5.42	-	-	-	-
3 ancient beach ridges	3	26-27	4.39	4.39	-	-	-	-
4 ancient beach ridges	4	1-7	20.12	9.03	10.41	1-3	10 000	3b 10 000
5 fill deposits	5	2-8	7.48	7.48	-	-	-	-
3 fill deposits	5-6	14-16	2.84	2.84	-	-	-	-
4 fill deposits	6-7	1-4	11.35	11.35	-	-	-	-
4 glaciofluvial deposits	6-7	11-24	49.54	34.83	4.21	1-6	370 000	3b 370 000
Pennells Hill and Marlbank eskers	10-11	8-20	68.89	11.61	17.69	1-6	1 750 000	3a 1 750 000

TABLE 16 - SAND AND GRAVEL RESOURCES - SHEFFIELD TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
Beaver Lake, White Lake esker	1-5	4-11	83.86	10.84	54.40	1-7	770 000	3a 760 000 3b 10 000
6 glaciofluvial deposits	3	10-11	8.26	8.26	-	-	-	-
7 glaciofluvial deposits	2-3	11-12	22.70	7.22	7.56	1-4	290 000	3a 290 000
8 glaciofluvial ridges	1-2	15-16	38.18	6.97	11.19	1-6	730 000	3a 270 000 3b 460 000
Tamworth esker southwest of Tamworth	4-5	1-4	14.70	3.61	3.58	1-7	200 000	3a 200 000
Tamworth esker southeast of Tamworth	6-9	1-4	53.92	5.93	26.53	1-7	810 000	3a 810 000
4 glaciofluvial deposits around Tamworth	6-7	3-7	25.29	4.39	20.90	1-7	-	-
6 glaciofluvial deposits	1-2	26-31	9.03	9.03	-	-	-	-
12 glaciofluvial deposits	1-3	17-19	43.34	18.06	16.63	1-4	250 000	3a 250 000
4 fill deposits	3	14-16	9.29	9.29	-	-	-	-

(Continued)

TABLE 16 - SAND AND GRAVEL RESOURCES - SHEFFIELD TOWNSHIP (Cont'd)

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
4 glaciofluvial deposits	5	11-14	18.57	4.90	9.90	1-4	100 000	3a 100 000
8 fill deposits	5-6	18-21	14.19	14.19	-	-	-	-
6 fill deposits	3-4	19-20	7.22	7.22	-	-	-	-
4 glaciofluvial ridges	3-4	21-23	9.81	4.13	0.16	1-3	120 000	3a 120 000
Salmon River glacio-fluvial ridges	7-10	11-13	94.69	39.73	18.01	1-7	1 210 000	3a 1 210 000
Glaciofluvial ridges along County Road 15	7-13	13-25	111.20	39.73	49.26	1-8	1 080 000	1a 180 000 1b 490 000 3a 410 000

TABLE 17 - SAND AND GRAVEL RESOURCES - SOUTH FREDERICKSBURGH TOWNSHIP

Nature-Location of Deposit	Conc. No.	Lot No.	Area of Deposit (ha)	Low Grade Area (ha)	Extracted and/or Sterilized Area (ha)	Depth (m)	Volume (Cubic Metres)	Material Classification (Cubic Metres)
6 ancient beach ridges	Ad.Conc 1	6-12	14.19	14.19	-	-	-	-
4 ancient beach ridges	Ad.Conc 2	6-12	13.93	13.93	-	-	-	-
2 ancient beach ridges	Ad.Conc 3	1-3	4.39	4.39	-	-	-	-
2 ancient beach ridges	2	5-8	7.48	7.48	-	-	-	-
3 ancient beach ridges	1-2	6-9	11.35	11.35	-	-	-	-
2 ancient beach ridges	1	1-2	10.84	10.84	-	-	-	-
4 fill deposits near Sandhurst	1	9	7.42	7.42	-	-	-	-
2 ancient beach ridges	2	12-16	6.19	6.19	-	-	-	-
5 ancient beach ridges	2-3	14-19	19.61	19.61	-	-	-	-
3 ancient beach ridges east of Hay Bay	3	14-19	20.38	14.96	-	1-4	110 000	3a 110 000
7 ancient beach ridges	3	20-26	19.09	19.09	-	-	-	-
7 ancient beach ridges near Galts Corners	2	20-26	26.77	3.10	5.27	1-3	210 000	3a 210 000
2 glaciofluvial deposits	Additional Concession 3	11-12	4.64	-	4.64	1-5	-	-

TABLE 18 - ONTARIO MINISTRY OF NATURAL RESOURCES BOREHOLE DESCRIPTIONS: ABBREVIATIONS

MATERIAL ABBREVIATIONS

Fill	fill
Top Soil	tpsl
Clay	clay
Silt	silt
Fine Sand	fsnd
Medium Sand	msnd
Coarse Sand	csnd
Gravel	grvl
Stones	stns
Boulders	bldr
Till	till
Bedrock	bdrk
Layered	lyrs
Refusal	rfsl
Watertable	wt

TOWNSHIP ABBREVIATIONS

Abinger	Ab
Adolphustown	Ao
Amherst Island	Ah
Anglesea	Ag
Ashby	As
Camden East	CE
Denbigh	Dn
Effingham	Ef
Ernestown	Er
Kaladar	Ka
North Fredericksburgh	NF
Richmond	Ri
Sheffield	Sh
South Fredericksburgh	SF

TABLE 19 - ONTARIO MINISTRY OF NATURAL RESOURCES BOREHOLE DESCRIPTIONS

BOREHOLE NUMBER	TOWNSHIP	LOT	CON	MATERIAL DESCRIPTION
1	Ef	28	13	stns fsnd silt lyrs 3.66,stns fsnd lyrs 4.57,grvl sfsnd 5.49,stns asnd 7.62,wt 6.8
2	Ef	34	12	tpsl 0.30,stns casnd 1.98,casnd 4.27,stns casnd lyrs 12.19,casnd stns 14.48,bdrk @ 13.72
3	Ef	32	13	tpsl 0.20,sfsnd 2.13,stns sfsnd 2.44,sfsnd stns lyrs 7.62,asnd 10.67
4	As	34	4	tpsl 0.20,asnd grvl 0.91,casnd 1.98,casnd grvl 2.44,fsnd 4.88,bdrk
5	As	15	16	tpsl 0.15,stns sfsnd lyrs 4.57,stns casnd lyrs 9.14,sfsnd 10.67,stns sfsnd lyrs 13.72
6	As	17	16	tpsl 0.15,fsnd 1.52,stns scsnd lyrs 3.35,fsnd 4.72,stns asnd 5.22,fsnd 9.75,stns sfsnd lyrs 13.24,fsnd 13.85,grvl asnd 16.76,till 17.37,bdrk
7	As	17	16	tpsl 0.15,stns asnd 2.29,bdrk
8	As	17	16	tpsl 0.15,fsnd silt lyrs 6.71,till 7.62
9	Dn	33	11	tpsl 0.15,scsnd grvl 2.13,stns scsnd lyrs 4.57,stns silt fsnd lyrs 6.86,till 8.38 rfsl
10	Dn	33	11	tpsl 0.15,scsnd grvl 0.91,fsnd 1.22,scsnd grvl 3.05,rfsl
11	Dn	34	11	tpsl 0.15,stns casnd lyrs 7.62,wt 7.16
12	Dn	23	9	stns casnd 1.52,scsnd grvl 2.74,casnd 3.96,scsnd grvl 4.57,stns casnd 6.10,stns csnd 7.21,csnd grvl 17.92
13	Dn	14	9	tpsl 0.15,stns casnd 2.29,silt stns fsnd 3.05,stns sfsnd 6.10,fsnd 7.92,casnd grvl 8.84,grvl casnd 10.06,stns casnd lyrs 12.50,rfsl
14	Dn	14	9	tpsl 0.10,stns sfsnd lyrs 3.05,stns fsnd 4.86,asnd stns 5.35,stns sfsnd 6.10,asnd stns 6.86,silt sfsnd lyrs 7.62,stns casnd lyrs 9.14,csnd grvl 10.21,stns asnd lyrs 12.21,grvl csnd 12.80,stns asnd lyrs 17.37,grvl scsnd 18.29,stns fsnd lyrs 21.34
15	Dn	14	9	fsnd 1.98,stns sfsnd lyrs 3.96,silt stns sfsnd lyrs 6.10,stns casnd lyrs 7.01,stns asnd lyrs 9.30,asnd grvl 10.00,asnd 10.36,grvl asnd lyrs 11.28,asnd 11.58,stns fsnd 12.50,fsnd 12.80,stns fsnd lyrs 15.24,wt 14.02
16	Dn	15	9	tpsl 0.10,silt stns fsnd lyrs 5.79,stns asnd 7.01,stns fsnd lyrs 8.23,till 8.53, bdrk
17	Dn	15	9	tpsl 0.10,stns casnd lyrs 6.10,stns asnd 9.45,silt fsnd lyrs 10.01,fsnd 17.06,silt 17.36,fsnd 20.42,till 21.34,rfsl
18	Dn	15	9	tpsl 0.10,stns asnd 8.23,grvl csnd 10.06,silt stns scsnd lyrs 9.14
19	Dn	19	16	tpsl 0.10,fsnd 3.35,stns asnd lyrs 7.62,grvl casnd 12.19,wt 9.14
20	Dn	19	16	tpsl 0.10,fsnd 0.91,grvl casnd 1.83,stns casnd 4.57,silt stns asnd lyrs 7.62,wt 5.18

21	Bn	19	16	csnd grvl 1.83,rfsl
22	Bn	19	16	csnd 1.68,stns fsnd 3.35,grvl esnd 4.57,rfsl
23	Bn	16	12	tpsl 0.10,fsnd 1.83,stns fesnd 2.13,fsnd 3.66,stns esnd lyrs 4.11,esnd 4.27,grvl esnd lyrs 5.03,esnd 5.49,esnd grvl 7.01,rfsl
24	Bn	16	12	tpsl 0.10,silt fsnd lyrs 3.60,grvl esnd 4.42,bdrk
25	Bn	16	12	tpsl 0.10,grvl cesnd 1.37,stns efsnd 4.57,efsnd 6.10,stns esnd lyrs 7.01,esnd stns esnd 9.45,bdrk
26	Bn	14	12	tpsl 0.10,ecsnd grvl 2.29,stns cesnd 4.11,cesnd grvl lyrs 6.10,grvl cesnd 7.62 fesnd lyrs 10.67,grvl esnd 12.19
27	Bn	14	12	tpsl 0.10,fsnd 6.10,stns fsnd 9.14,stns fesnd lyrs 10.67,efsnd 13.41
28	Bn	15	12	tpsl 0.10,stns esnd 1.98,efsnd 7.62,fsnd 13.26,bdrk
29	Bn	9	15	tpsl 0.10,fsnd 4.57,stns fesnd 7.01,stns esnd 12.19,wt 7.01
30	Bn	9	15	tpsl 0.10,efsnd 3.96,silt stns fesnd lyrs 13.55,till 15.85,rfsl
31	Bn	9	14	tpsl 0.10,esnd grvl 2.44,stns esnd 4.57,stns fsnd lyrs 13.74
32	Bn	9	14	tpsl 0.10,fsnd 9.14
33	Bn	12	1	tpsl 0.10,grvl 3.66,cesnd 5.18,cesnd grvl 7.62,wt 6.10
34	Bn	18	3	esnd 1.68,stns esnd 3.05,stns esnd lyrs 5.64,silt 6.10,bdrk wt 5.18
35(a)	Ab	12	7	tpsl 0.10,grvl 0.76,ecsnd 2.44,ecsnd 3.35,grvl ecsnd 4.57,ecsnd grvl 4.88,stns ecsnd 5.64,till 6.10,bdrk
35(b)	Ab	13	6	tpsl 0.10,stns cesnd 2.44,fsnd 4.57,wt 2.44
36	Ab	25	14	tpsl 0.10,stns cesnd 2.13,silt stns fesnd lyrs 3.05,fsnd 6.10,wt 5.18
37	Bn	6	4	tpsl 0.10,stns efsnd 3.05,fsnd 9.14
38	Bn	5	5	tpsl 0.10,fesnd 3.35,silt clay 4.57,wt 3.66
39	Bn	11	1	tpsl 0.10,cesnd grvl lyrs 1.83,cesnd 1.98,cesnd grvl 2.59,cesnd 3.05,grvl cesnd lyrs 3.79,bdrk
40(a)	Bn	11	1	tpsl 0.10,grvl ecsnd 1.83,bdrk
40(b)	Bn	11	1	tpsl 0.10,grvl ecsnd 1.83,bdrk
41	Bn	11	1	tpsl 0.10,cesnd grvl lyrs 2.74,cesnd 3.66,bdrk
42	Ab	30	12	efsnd 10.06,bdrk
43	Ab	30	12	tpsl 0.10,fsnd 7.62,silt clay 27.43,stns silt clay 28.96,wt 3.66

		east range		
44(a)	Ab	34	35	tpsl 0.10,casnd grvl 2.59,rfsl
		east range		
44(b)	Ab	34	35	tpsl 0.10,casnd grvl lyrs 2.13,stns fasnd 3.51,casnd grvl 5.18,rfsl
45	Ab	31	12	mfsnd 0.91,fsnd 4.27,silt clay 6.10
46	Ef	3	11	fasnd 3.90,silt fsnd 9.14,silt clay 10.67
47	Ef	2	9	fill 2.13,fsnd stns till 8.84,bdrk wt 6.40
48	Ef	1	8	tpsl 0.10,grvl casnd 3.05,stns mfsnd lyrs 4.88,grvl msnd 5.33,mfsnd 6.10,stns fas- lyrs 9.14,fsnd 11.89,msnd grvl 14.17,fsnd 18.59,bdrk wt 13.72
49	Ka	11	1	grvl casnd 6.10,stns casnd lyrs 10.67,stns mfsnd lyrs 13.10,wt 12.50
50	Ka	19	3	tpsl 0.10,stns fsnd lyrs 2.88,fsnd 7.62,wt 4.27
51	Sh	17	9	tpsl 0.1,stns csnd 1.52,grvl csnd lyrs 6.10,bdrk wt 4.88
52	Sh	16	9	tpsl 0.1,grvl csnd 4.88,bdrk

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APPENDIX B - GLOSSARY

ABRASION RESISTANCE: Tests such as the Los Angeles abrasion test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

ABSORPTION CAPACITY: Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

AGGREGATE: Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

ALKALI-AGGREGATE REACTION: A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for structural concrete uses.

BLENDING: Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

CAMBRIAN: The first period of the Palezoic Era, thought to have covered the time between 570 and 500 million years ago. The Cambrian precedes the Ordovician Period.

CLAST: An individual constituent, grain or fragment of a sediment or rock, produced by the mechanical weathering of larger rock mass. Synonyms include particle and fragment.

CRUSHABLE AGGREGATE: Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

DELETERIOUS LITHOLOGY: A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions.

DEVONIAN: A period of the Paleozoic Era thought to have covered the span of time between 395 and 345 million years ago, following the Silurian Period. Rocks formed in the Devonian Period are among the youngest found in Ontario.

DOLOSTONE: A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

DRIFT: A general term for all unconsolidated rock debris transported from one place and deposited in another, distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

DRUMLIN: A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were formed beneath an advancing ice sheet, and were shaped by its flow.

EOLIAN: Pertaining to the wind, especially with respect to landforms whose constituents were transported and deposited by wind activity. Sand dunes are an example of an eolian landform.

FINES: A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

GLACIAL LOBE: A tongue-like projection from the margin of the main mass of an ice cap or ice sheet. During the Pleistocene Epoch several lobes of the Laurentide continental ice sheet occupied the Great Lakes basins. These lobes advanced then melted back numerous times during the Pleistocene, producing the complex arrangement of glacial material and landforms found in southern Ontario.

GNEISS: A coarse-textured metamorphic rock with minerals arranged in parallel streaks or bands, but without the ability to be separated easily along parallel planes (i.e. schistosity). Gneiss is relatively rich in feldspar. Other common minerals found in this rock include quartz, mica, amphibole, and garnet.

GRADATION: The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulder	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

GRANITE: A coarse-grained, light-coloured rock that ordinarily has a uniform appearance or texture and is composed of quartz, and feldspar with either mica, hornblende, or both.

GRANULAR BASE COURSE: Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

HOT-LAID (OR ASPHALTIC) AGGREGATE: Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3 and 4), or as binder course (H.L. 2 and 8) used to bind the surface course to the underlying granular base course.

LITHOLOGY: The description of rocks on the basis of such characteristics as color, structure, mineralogic composition and grain size. Generally, the description of the physical character of a rock.

MAGNESIUM SULPHATE SOUNDNESS TEST: This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible will usually break down and give high losses in this test.

MELTWATER CHANNEL: A drainage way, often terraced, produced by water flowing away from a melting glacier margin (see also SPILLWAY).

ORDOVICIAN: an early period of the Paleozoic Era thought to have covered the span of time between 500 and 435 million years ago.

PALEOZOIC ERA: One of the major divisions of the geologic time scale thought to have covered the time between 570 and 230 million years ago, the Paleozoic Era (or Ancient Life Era) is subdivided into six geologic periods, of which only four (Cambrian, Ordovician, Silurian and Devonian) are represented in southern Ontario.

PETROGRAPHIC EXAMINATION: An aggregate quality test based on known field performance of various rock types. The test

result is a Petrographic Number (P.N.). The higher the P.N. the lower the quality of the aggregate.

PLEISTOCENE: An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

POSSIBLE RESOURCE: Reserve estimates based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

PROBABLE RESOURCE: Reserve estimates of material based on some specific knowledge of the geologic character of the deposit and for which there are samples and measurements. The estimates are based on assumed continuity between test locations.

PRECAMBRIAN: All geologic time, and its corresponding rocks, before the beginning of the Paleozoic; it is equivalent to about 90% of geologic time. Precambrian time has been divided according to several different systems, all of which use the presence or absence of evidence of life as a criterion.

SHALE: A fine-grained, sedimentary rock formed by the consolidation of clay, silt or mud and characterized by well developed bedding planes, along which the rock breaks readily into thin layers. The term shale is also commonly used for fissile claystone, siltstone and mudstone.

SILURIAN: An early period of the Palezoic Era thought to have covered the time between 435 and 395 million years ago. The Silurian follows the Ordovician Period and precedes the Devonian Period.

SOUNDNESS: The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

TILL: Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

WISCONSINAN: Pertaining to the last glacial period of the Pleistocene Epoch in North America. The Wisconsinan began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of southern Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

APPENDIX C - GEOLOGY OF SAND AND GRAVEL DEPOSITS

The type, distribution, and extent of sand and gravel deposits in Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces

These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous because of extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive because of the variability of the deposits both in terms of quality and grain size distribution.

Kames

Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuties. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine-grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the rare presence of excess fines (silt- and clay-sized particles).

Eskers

Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift

This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits because of their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Ice-marginal Deltas

These formed when streams or rivers of glacial meltwaters entered into lakes with subsequent deposition of transported sediments. In Ontario these deposits tend to consist mainly of sand and much silt. However in near ice or ice-contact situations coarse material may be present. In other situations channel fills may provide coarse material or the upper beds (topsets) of the delta may essentially consist of outwash gravel. Although deltaic deposits may be very large, the probability of obtaining coarse material is generally low.

Outwash

Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the ice lobes. The deposits occur as sheets or as terraced valley fills (valley

trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Spillway

This is the term for early post-glacial drainage routes which were characterized by higher discharges than modern river systems. The source of increased discharge was the draining of glacial lakes as a response to the melting of ice dams, and increased amounts of water released by the melting of shrinking ice sheets. Grading and sorting of the material ranges from variable to very consistent. Presently, many spillway deposits provide sources for crushable aggregate (see also MELTWATER CHANNEL).

Alluvium

Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and they have generally low value because of the presence of excess silt- and clay-sized material. There are few large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits

These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of southern Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the source material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas

These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In southern Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present. Although deltaic deposits may be large, the probability of obtaining coarse material is generally low.

Glaciolacustrine Plains

The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources because of their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines

These are belts of glacial drift deposited at, and parallel to, glacier margins. End moraines commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Eolian deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in southern Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments almost always consists of fine to coarse sand and are usually well sorted. The probabiltiy of locating crushable aggregate in windblown deposits is very low.

APPENDIX D - GEOLOGY OF BEDROCK DEPOSITS

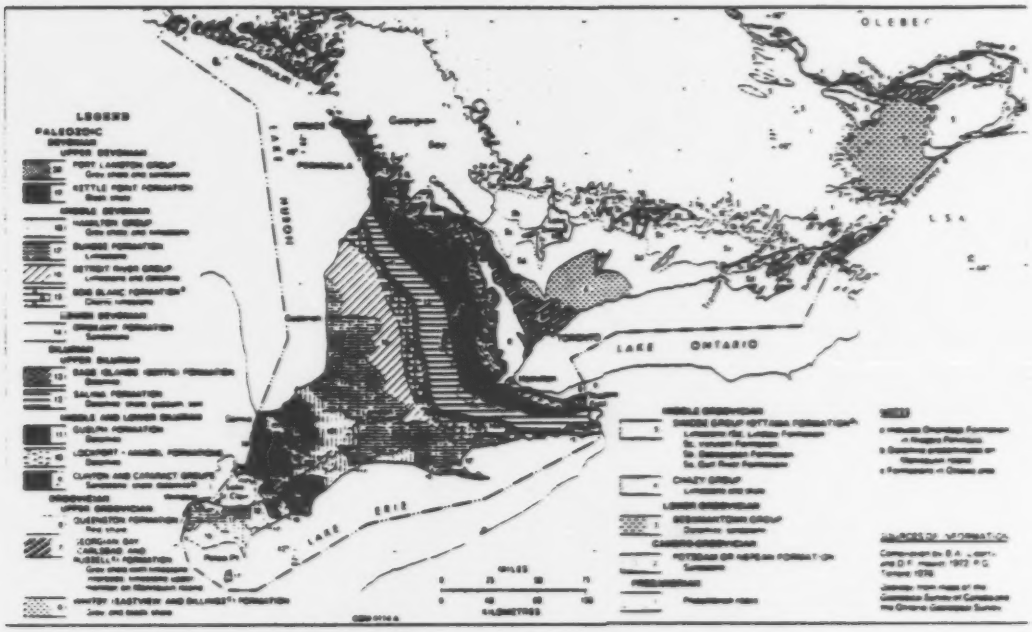

Figure 2 - Bedrock Geology of Southern Ontario

BEDROCK SUITABLE FOR CRUSHED STONE PRODUCTS

Bass Islands Formation (Upper Silurian)

(Includes the Bertie Formation of the Niagara Peninsula) Composition: Medium- to massive-bedded, aphanitic, brown dolostone with shaly partings. Thickness: 11 to 18 metres thick near Hagersville. Uses: Quarried for crushed stone on the Niagara Peninsula at Fort Erie, Cayuga, Hagersville, and Dunnville. Los Angeles Abrasion Test: 17-35% loss; Absorption: 1.4%. Shaly parts are unsuitable for aggregate because of high soundness losses.

Bobcaygeon Formation (Middle Ordovician)

Composition: Compact, homogeneous, medium- to thin-bedded, fine-grained limestone with some argillaceous and shaly partings. Thickness: The lower unit is 12 to 22 metres thick in the east and the remainder of the formation is 12 metres thick. Uses: Quarried at Kirkfield and Marysville for crushed stone. The Bobcaygeon Formation has consistently acceptable quality for granular base course materials and concrete.

Bois Blanc Formation (Lower-Middle Devonian)

Composition: Brownish grey, medium-crystalline, medium- to thin-bedded, cherty limestone, commonly fossiliferous. Limestone may be silty or sandy in places. Thickness: 3 to 61 metres. Uses: Quarried at Hagersville, Cayuga, and Port Colborne for crushed stone. High cherty content makes much of the material unsuitable for concrete aggregate. Los Angeles Abrasion Test: 14-28% loss; Soundness Test: 4-10% loss; Absorption: 0.7-2.0%.

Dundee Formation (Middle Devonian)

Composition: Fine- to medium-crystalline, brownish grey, medium- to thick-bedded, dolomitic limestone with shaly partings, sandy layers, and chert in some areas. Thickness: 18 to 49 metres. Uses: Quarried near Port Dover and Pelee Island for crushed stone. Used at St. Marys as raw material for portland cement. Los Angeles Abrasion Test: 22-32% loss; Absorption: 0-4%.

Gull River Formation (Middle Ordovician)

Composition: Lower Member: interbedded silty dolostone, lithographic to fine crystalline limestone and fine-grained calcareous quartz sandstone. Upper Member: lithographic to fine-crystalline limestone. Uses: Quarried for crushed stone. The Lower Member contains alkali reactive layers and physically unsound beds.

Lindsay Formation (Middle Ordovician)

Composition: Interbedded sublithograhic to fine-crystalline limestone, commonly nodular, calcareous shale and calcarenite. Two members are mappable. Shale occurs in interbeds up to 5 cm thick in the Lower Member, and is more abundant in the Upper Member. Uses: Quarried for crushed stone in Prince Edward County.

Lockport and Amabel Formations (Middle Silurian)

Composition: Amabel Formation (Waterdown to the Bruce Peninsula): massive, fine-crystalline dolostone, with reef facies dolostone near Georgetown. Lockport Formation (lateral facies equivalent to the Amabel Formation from Waterdown to Niagara Falls): thin- to massive-bedded, fine- to medium-grained dolostone. Thickness: Amabel Formation: maximum observed thickness of 26 metres. Lockport Formation: up to 40 metres. Uses: The Lockport and Amabel Formations have been used to produce lime, crushed stone, concrete aggregate and building stone throughout their area of occurrence, and are a resource of provincial significance. Los Angeles Abrasion Test: 21-35% loss; Soundness Test: 2.0% loss; Absorption: 0.4-1.6%.

March Formation (Lower Ordovician)

Composition: Interbedded quartz sandstone, sandy dolostone and dolostone. This formation represents a transition from pure sandstone of the Nepean Formation to pure dolostone of the Oxford Formation. Uses: Dolomitic sandstone of the March Formation makes excellent skid resistant aggregate. The material is quarried for this purpose near Brockville an southeast of Ottawa.

Onondaga Formation (Middle Devonian)

(Equivalent to the Detroit River Group, with a textural change) Composition: Edgecliff Member: medium-bedded, fine- to medium-grained, dark grey cherty limestone with an estimated thickness of 25 to 30 feet (8 to 9 m). Clarence Member: massive-bedded, dark grey-brown, fine-grained, very cherty limestone having estimated thickness of 26 feet (8 m). Moorehouse Member: medium-bedded, dark grey-brown or purplish brown, fine- to coarse-grained, variably cherty limestone with an estimated thickness of 15 to 25 feet (5 to 8 m). Uses: Quarried for crushed stone on the Niagara Peninsula at Welland and Port Colborne. High cherty content makes much of the material unsuitable for concrete aggregate.

Ottawa Group (Middle Ordovician)

Composition: Mainly limestone. The Ottawa Group has recently been correlated with units of the Black River and Trenton Groups (Williams and Rae 1983). The Ottawa Group consists of Shadow lake, Gull River, Bobcaygeon, Verulam and Lindsay Formations.

Oxford Formation (Lower Ordovician)

Composition: Medium- to thick-bedded, grey dolostone, with some shaly partings. Thickness: 73 metres. Uses: Quarried for crushed stone (road and concrete aggregate) at Ottawa, Brockville, and Smiths Falls.

Precambrian Rocks (Precambrian)

Composition: Metamorphosed volvanic rocks, clastic and chemical metasediments, and plutonic rocks. Uses: Many of the Precambrian rocks would make sound aggregate, but their use is very limited because of high processing costs.

Rockcliffe Formation (Middle Ordovician)

Composition: Lower Member: Interbedded, fine-grained light greenish-grey quartz sandstone and green shale. The upper part of the formation is characterized by interbeds of silty dolomite, sublithographic to fine crystalline limestone with

shaly partings, and calcarenite (St. Martin Member). Uses: The St. Martin Member calcarenite has been quarried for crushed stone near Hawkesbury.

Verulam Formation (Middle Ordovician)

(See next page)

BEDROCK SUITABLE FOR LIME PRODUCTION AND OTHER CHEMICAL USES

Detroit River Group (Middle Devonian)

(Equivalent to the Onondaga Formation in the Niagara Peninsula, with a textural change) Composition: Near Beachville, the group consists of medium- to micro-crystalline, medium-bedded, high-purity limestone. It grades northwards near St. Marys to soft, evenly bedded, fine-grained dolostone with bituminous laminae. Massive, porous, reef facies material also occurs to the north (Formosa Reef Limestone). Thickness: 30 metres at Beachville, 107 metres at Clinton. Uses: The most important source of high-purity limestone in Ontario is the Lucas Formation of the Detroit River Group at Beachville. Detroit River limestone produces much of Ontario's lime and cement. The Anderdon Member of the Lucas Formation is quarried at Amherstburg for crushed stone.

Grenville Marble (Precambrian)

Composition: Recrystallized fine- to coarse-grained white limestone and dolostone, usually of high chemical purity. Uses: Lime production, but also in small amounts for terrazzo chips, poultry grit, decorative stone, and building stone.

Guelph Formation (Middle Silurian)

Composition: Aphanitic to medium-crystalline, thick-bedded, soft, porous dolostone, characterized in places by extensive vuggy, porous reefal facies dolostone of high chemical purity. Thickness: 30 to 52 metres. Uses: The main use is for dolomitic lime in the construction industry. The formation is quarried near Hamilton and Guelph.

Lindsay Formation (Upper Ordovician)

Composition: fine-crystalline, rubbly, nodular-weathering limestone. Collingwood Member: organic-rich interbedded calcareous shales and limestones. Uses: Quarried at Picton, Ogden Point and Bowmanville for cement. The formation is generally unsuitable for crushed stone, concrete aggregate, or granular base course.

Verulam Formation (Middle Ordovician)

Composition: Fossiliferous, pure to argillaceous limestone and interbedded calcareous shale. The rock is not resistant to erosion and commonly weathers to rubble. Thickness: 60 to 90 m. Uses: Quarried at Picton, Ogden Point, and Mara Township for use in cement manufacture. The formation is generally unsuitable for crushed stone because of clay impurities, many clayey interbeds, and low abrasion resistance, high soundness losses and poor freeze and thaw resistance. However it has been quarried for crushed stone in Lennox and Addington County.

BEDROCK SUITABLE FOR BRICK AND TILE MANUFACTURE

Georgian Bay Formation (Upper Ordovician)

(Formerly known as the Meaford-Dundas and Blue Mountain shales in the Toronto and Bruce Peninsula areas)
Composition: Soft, fissile, blue-grey shale with limey or sandy lenses in a few places. Thickness: 195 metres at Toronto. Uses: Several producers in the vicinity of Metro Toronto produce brick and structural tile. Lightweight aggregate has been produced at Streetsville by heat expansion of the shale.

Hamilton Group (Middle Devonian)

Composition: Grey shale with interbeds of crystalline and cherty limestone. The group has six formations, but only the Arkona Formation is of commercial value. It is a soft, light grey, calcareous shale which is plastic and easily worked when wet. Thickness: 24 to 91 metres. The Arkona Formation has a thickness of 4 to 37 metres. Uses: The Arkona Formation is extracted at Thedford and near Arkona for production of drainage tile.

Queenston Formation (Upper Ordovician)

Composition: Red, thin- to thick-bedded, sandy to argillaceous shale with green mottling and banding. Thickness: 122 to 152 metres. Uses: There are several large shale quarries developed in the Queenston Formation in the Toronto-Hamilton region and one at Russell, near Ottawa. All produce brick for construction. The Queenston Formation is the most important source material for brick manufacture in the Province.

BEDROCK SUITABLE FOR OTHER INDUSTRIAL PRODUCTS

Nepean (Potsdam) Formation (Cambro-Ordovician)

Composition: Creamy, coarse-grained, silica sandstone. Uses: Quarried throughout its area of outcrop for building stone, decorative stone, abrasives, and for glass making.

Salina Formation (Upper Silurian)

Composition: Grey and red shale, brown dolomite, and, in places, salt, anhydrite, and gypsum. The formation consists predominantly of evaporite deposits with up to eight members identified. Uses: Gypsum is mined at Hagersville, Caledonia, and Drumbo. Salt is mined at Goderich and is produced from brine wells at Amherstburg, Windsor, and Sarnia.

Blue Mountain Formation (Upper Ordovician)

(Formerly known as the Whitby Formation) Composition: Blue-grey, predominantly non-calcareous shale. Uses: Quarried at Bowmanville for use in cement production.

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